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TR-1114

FLUID AMPLIFICATION

9. Logic Elements

E. V. Hobbs

8 March 1963

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DA-5N03-01-003
OMS Code 5010.11.71200
HDL Proj. 31100

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FLUID AMPLIFICATION

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E. V. Hobbs

FOR THE COMMANDER:
Approved by

R. D. Hatcher

R. D. Hatcher
Chief, Laboratory 300

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ILLUSTRATIONS

ABSTRACT

Descriptions are given of the operation of various fluid logic elements--singly and in combination.

1. INTRODUCTION

Certain fluid logic elements have been described by R. Warren.* In the present report the description of other useful elements is given along with the pertinent material that was presented previously. Because of the ease of working with low pressure air, most of the work at HDL on fluid amplifiers has been done using air as the working fluid. This report, therefore, concerns itself only with pneumatic operation.

Fluid amplifiers can have single-ended outputs or can be connected to use a push-pull effect. Operation can depend almost entirely on momentum exchange or can make use of the pressures resulting from the proximity of boundary walls. The mementum-exchange type of fluid amplifier can be designed so that its output is proportional to its input or it can be designed to be nonlinear or even bistable. The wall-interaction type on the other hand is difficult to make proportional over any reasonable range but lends itself very readily to becoming a bistable device. For this reason it is of considerable interest for use in binary systems.

2. LOGIC ELEMENTS

2.1 Flip Flops

A bistable device or element called a flip flop is shown in figure 1. The power jet stream enters at the bottom and flows upward through the nozzle. By the mechanism described by R. Warren**, the stream locks to one wall. When the power jet stream is locked to the left interaction chamber boundary wall as shown in figure 1, the pressure in the left control passage is well below the pressures in the input, output, interaction chamber, and right control passage. This low pressure should be maintained for good lock-on of the power jet stream to the wall. When this pressure is raised, flow into the interaction chamber from the control jet commences, and, if this flow reaches a certain threshold level, switching of the power jet to the right boundary wall will occur.

Fluid amplifiers can be built purposely one-sided so that the stream will always start on a certain side. This is done by making the boundary wall closer to the power jet on the side to which starting is desired. The stream will remain locked to that side until control flow is put in through one of the two control passages. As shown in figure 1, control flow introduced from the left side causes the stream to be shifted

*DOFL TR-1061, FLUID AMPLIFICATION, Fluid Flip Flops and a Counter, R. W. Warren.

**DOFL TR-1039, FLUID AMPLIFICATION, Basic Principles, R. Warren, S. Peperone.

from the left wall to the right wall, delivering energy to the right output. A right control flow can be used to shift the stream from the right wall to the left wall, delivering energy to the left output. Flip flops or bistable elements can be made to shift from one side to the other with a buildup in pressure at the output. They can also be made to remain where directed in spite of a large buildup in pressure at the output.

Figure 2 shows a memory flip flop. In this type of bistable element the distance from the exit of the power jet nozzle to the end of the divider or splitter is made relatively long to allow the stream to lock to one of the interaction boundary walls and remain locked to that wall, although there is a complete blockage on that output side.

Flip-flop elements can also be built with four control inputs, as shown in figure 3. This type of fluid element is useful where several input signals must be used to control one bistable fluid element. As shown in figure 3, two signals can be used to control the power jet to the right and two others to the left. The arrangement of the input passages for the control flows is such that very little interaction occurs between control flows. The configuration therefore provides an effective buffer between signals.

If a bistable element is properly designed, two signals (one from either side) can be introduced simultaneously and the larger will control the power jet to one output or the other. This type of fluid element can be used as a comparator (fig 4) to determine which of two inputs is larger. It can be used as a power amplifier for digital work where a larger signal is desired. In this case a bias is used for one of the two input signals, and the signal to be amplified is used on the other side. In this way, a pulse, of amplitude larger than the bias, delivered to the unbiased input causes the stream to switch, but when the pulse terminates, the bias shifts the power stream back to the opposite side and thereby terminates the output pulse.

Bistable fluid elements can also be made purposely to have no memory. Figure 5 shows a nonmemory flip flop. The distance between the output of the power jet and the end of the splitter has purposely been made short. This means that if a blockage occurs at the output, the stream does not have wall distance enough to continue locked to that boundary wall while flowing out of the unblocked side, and therefore it will be forced to turn and go out the other output passage, thereby attaching to the other wall, and no longer delivering its power to the blocked side.

2.2 Oscillators

Figure 6 shows an oscillator made using the nonmemory flip flop as the basis. In this oscillator, a tank with a slightly open valve is connected to one of the output passages of the nonmemory flip flop.

Valves are also placed at the control passages of the flip flop. These control valves are adjusted so that the power jet stream is directed to the tank when the tank is at a low pressure. As the pressure in the tank builds up it forces the stream to shift to the unloaded output, and it remains at the unloaded output until the pressure in the tank has fallen to some lower value, at which time the power jet stream can return to the tank output and allow the pressure to build up again. A useful square-wave output can be obtained as illustrated in figure 6, where the tank pressure and output flow are indicated.

Another type of oscillator, usually operating at higher frequency than the one in figure 6, is shown in figure 7. Again a non-memory flip flop is used. The two control passages are connected together by a piece of tubing of a given length. This tubing acts as a sonic path for a wave generated by the switching of the power jet stream from one side to the other. A rarefaction wave is initiated on the side to which the stream has switched. Simultaneously a pressure wave is initiated at the other control. These waves travel through the tubing crossing each other, and switching occurs when each of these reaches the other control passage which they do approximately at the same instant. This causes the power jet stream to switch to the opposite side after which the action reoccurs in the opposite direction. The sonic path then is approximately a half wavelength. Some secondary processes also occur which become more important as the tubing is shortened.

2.3 AND Gate

Another logic element known as the AND gate is shown in figure 8. This element has two input passages and three output passages. If flow is introduced at input A only, the output occurs at C because the stream clings to the left boundary wall. If input is introduced at B only, then the stream clings to the lower boundary wall and output occurs at D; however, when both A and B occur simultaneously the streams interact and output occurs at E, that is, flows occur at E only for inputs at both A and B.

2.4 OR Gate

The logic OR gate is shown in figures 9 and 10. In this element when there is no control flow, the power jet flows from the bottom to the top and clings to the wall on the left emerging at C. There are two input control passages, A and B, on the same side of the power jet, and flow from either of these two input passages will cause the power jet to come out of D. Therefore flow occurs at D for input at A <u>or</u> B.

3. COMBINATIONS OF ELEMENTS

3.1 Clock

A clock is shown in figure 11. This clock is similar to the low-frequency oscillator shown in figure 6. A biased flip flop (top left)

is connected to the output passage of the oscillator so that the high-energy power jet of the flip flop can be controlled to the left with oscillator input or to the right without oscillator input, because of the bias input. In this way pulses appear alternately at the two outputs of the biased flip flop, one being used as the primary clock pulse and the other as the secondary clock pulse, these two pulses never being present at the same time.

3.2 Half Adder

The logic half adder is shown in figure 12. In this combination of fluid elements, the AND gate of figure 8 is connected to the OR gate of figure 9. Output from the AND passage of the AND gate is one of the two half adder outputs. Output from either of the other passages of the AND gate flows to the control passages of the OR gate and is combined in the OR gate to provide the other half adder output. The NOR output of the OR gate is not used except as a dump. Therefore, the (A not B) or (B not A) output of the half adder comes from the OR gate, whereas the (A and B) output of the half adder comes from the AND gate.

Another type of half adder, the hook type, is shown in figure 13. Input occurring at A only clings to the left boundary wall and emerges at C. Input occurring at B only is turned by the hook and it also emerges at C. But in the presence of both A and B, stream interaction occurs and output is at D. Therefore, the half adder output at D is (A and B), but the half adder output at C is (A not B) or (B not A). This operation is shown in figure 14.

3.3 T Flip Flop

The T flip flop or trigger flip flop is shown in figure 15. In this combination a memory flip flop (top of figure) has its control passages connected to the output passages of a nonmemory flip flop without control passages. In this combination it is assumed that flow from the power jet of the memory flip flop is to the left emerging at output A. Flow to this side causes reduction to pressure in the left control passage below that in the right control passage. As shown in figure 16, this causes flow to occur from the left output of the nonmemory flip flop to the left input of the memory flip flop. The flow circulates through the controls of the memory flop flop from left to right and through the output passages of the nonmemory flip flop from right to left. This flow will force an input pulse that is initiated at the T input connection to go to the left, thereby raising the pressure in the left control passage of the memory flip flop and causing the stream to switch to output B. When the input pulse at the T connection terminates, the pressure ratios previously described are set up again but this time are reversed right to left, that is, the pressure is lower on the right side of the memory unit. Therefore the next input pulse occurring at the T connection will cause the output flow to change from B to A.

The above mechanism is of importance for relatively slow switching; however, J. Iseman and S. Katz have found a second mechanism which becomes of primary importance for rapid switching. This mechanism will be described in a subsequent report.

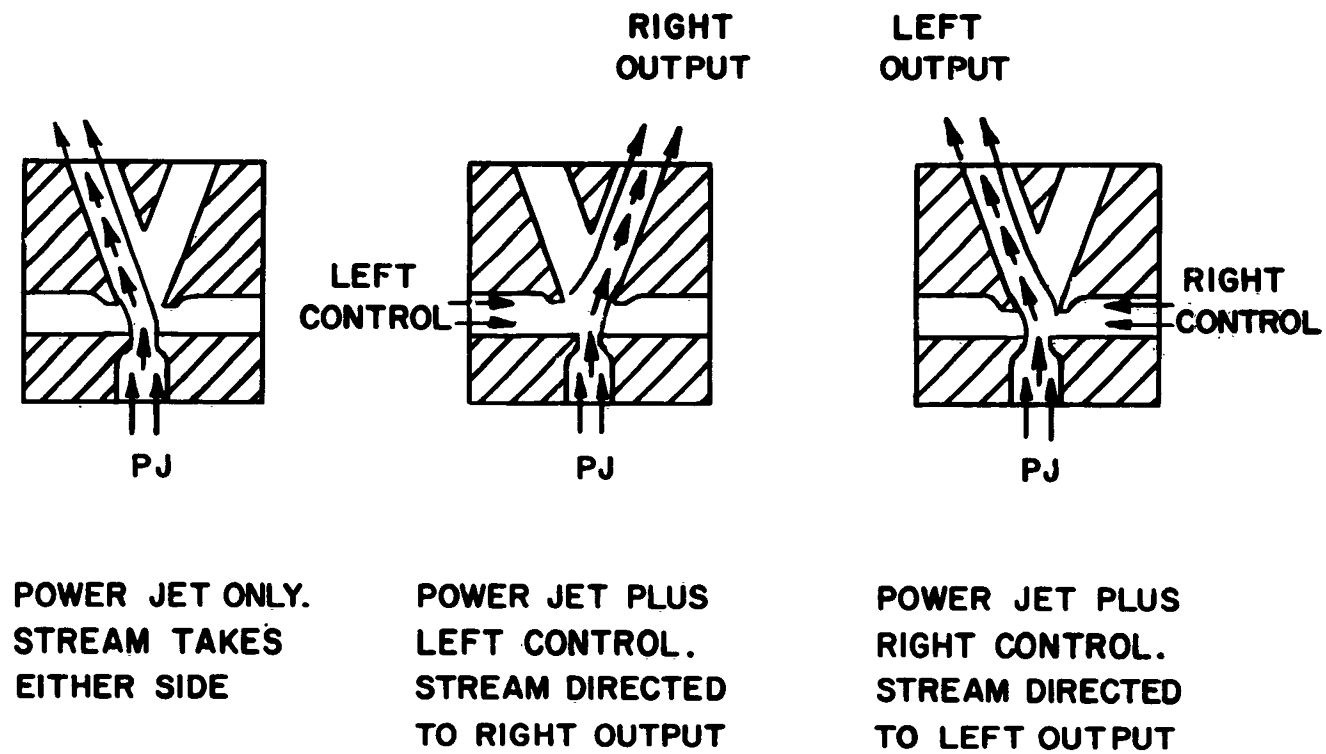

Figure 1. Flip flop.

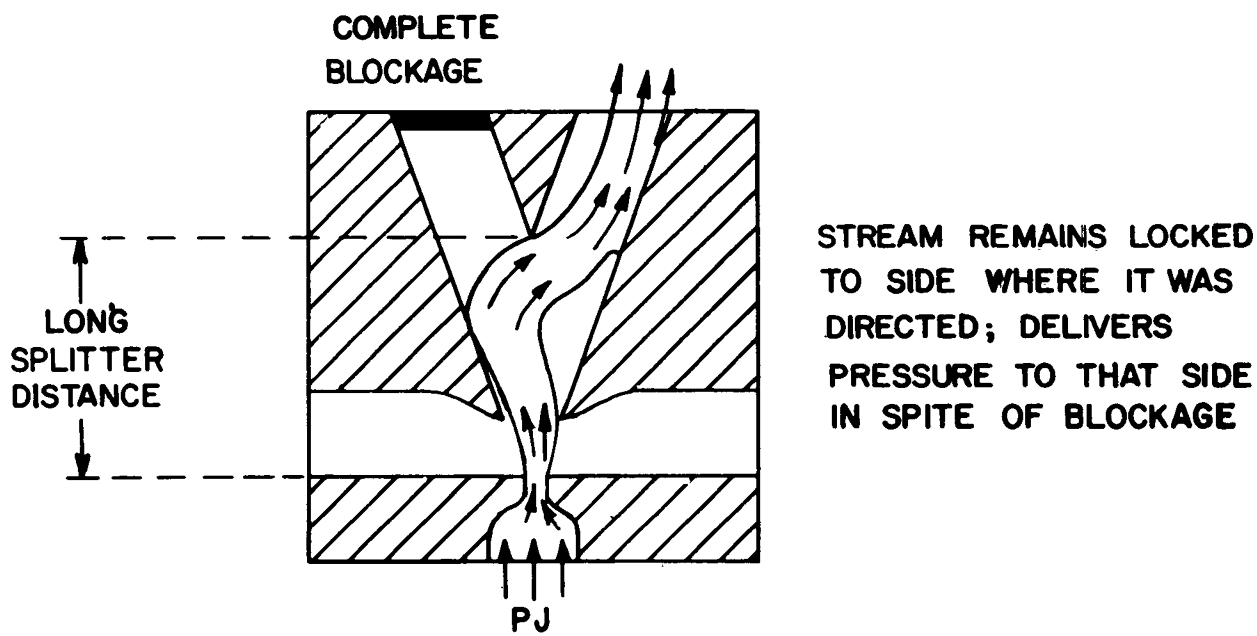

Figure 2. Memory flip flop.

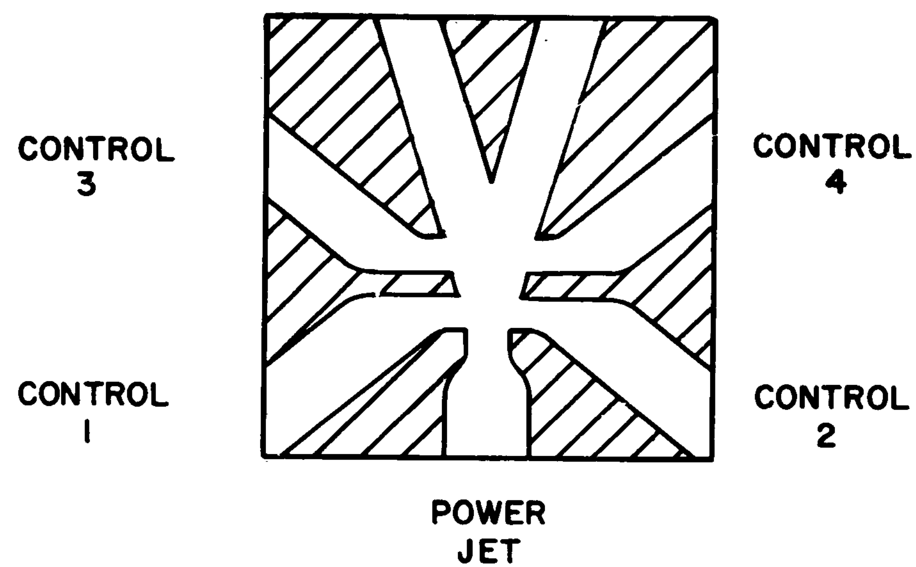

Figure 3. Four-Control flip flop.

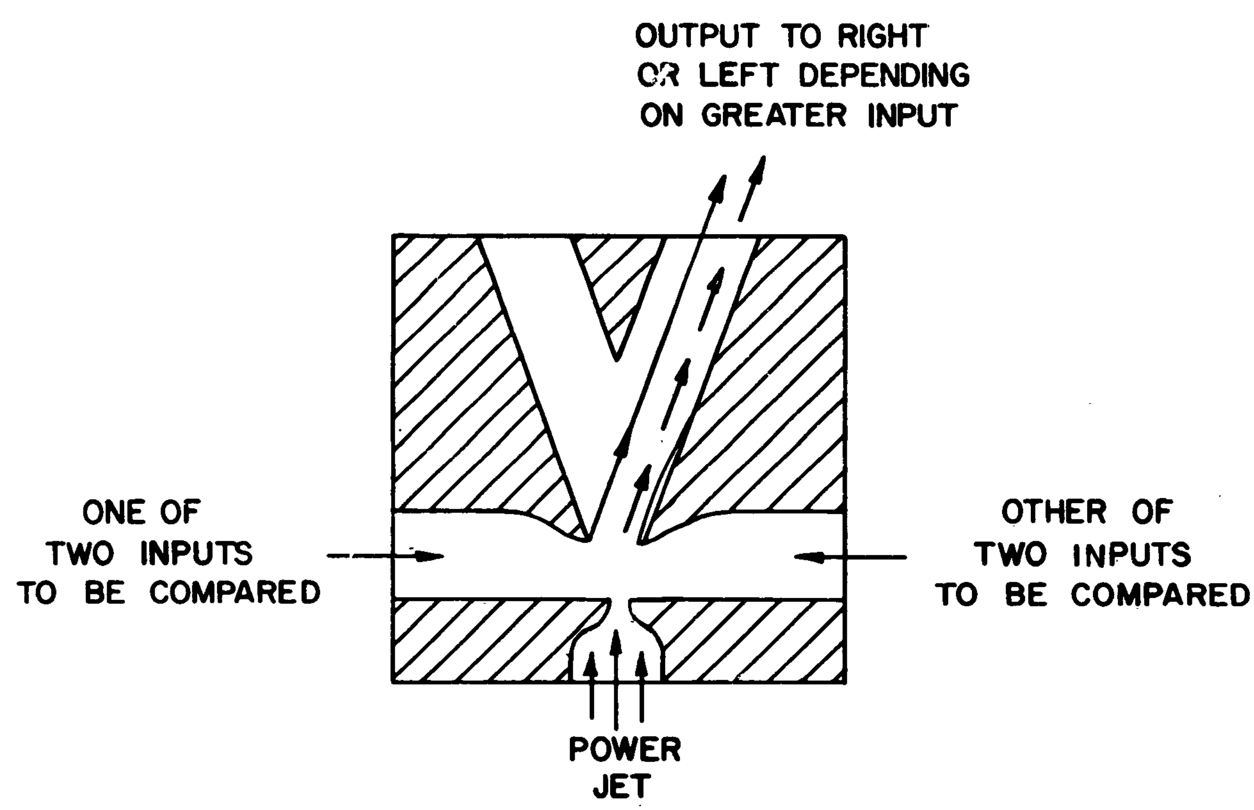

Figure 4. Comparator.

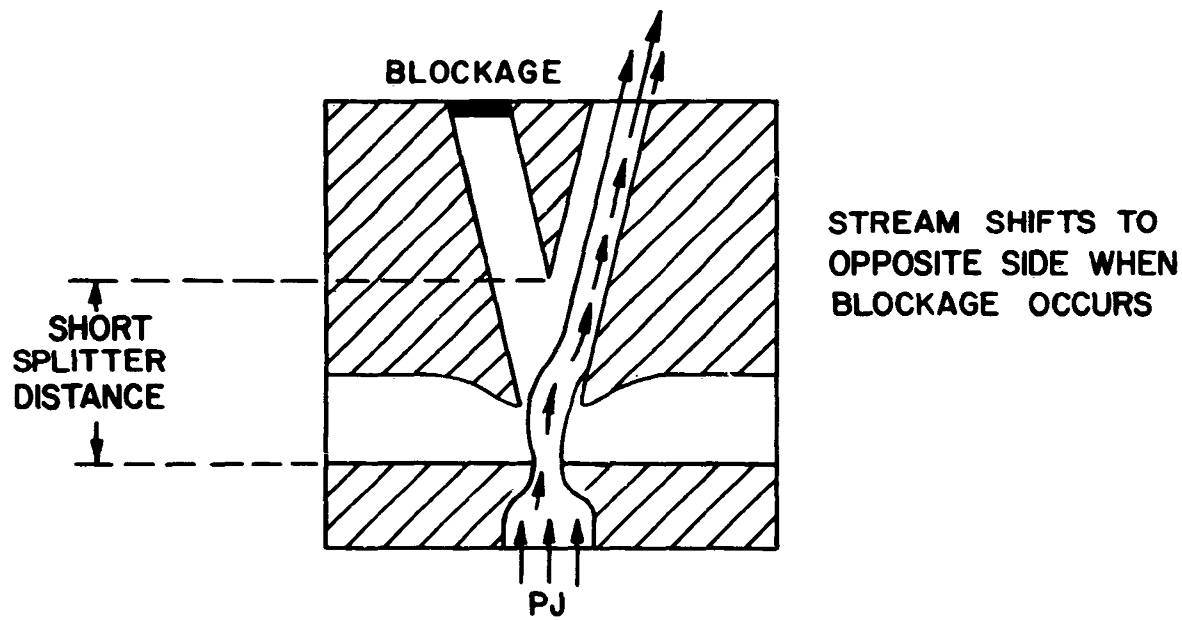

Figure 5. Nonmemory flip flop.

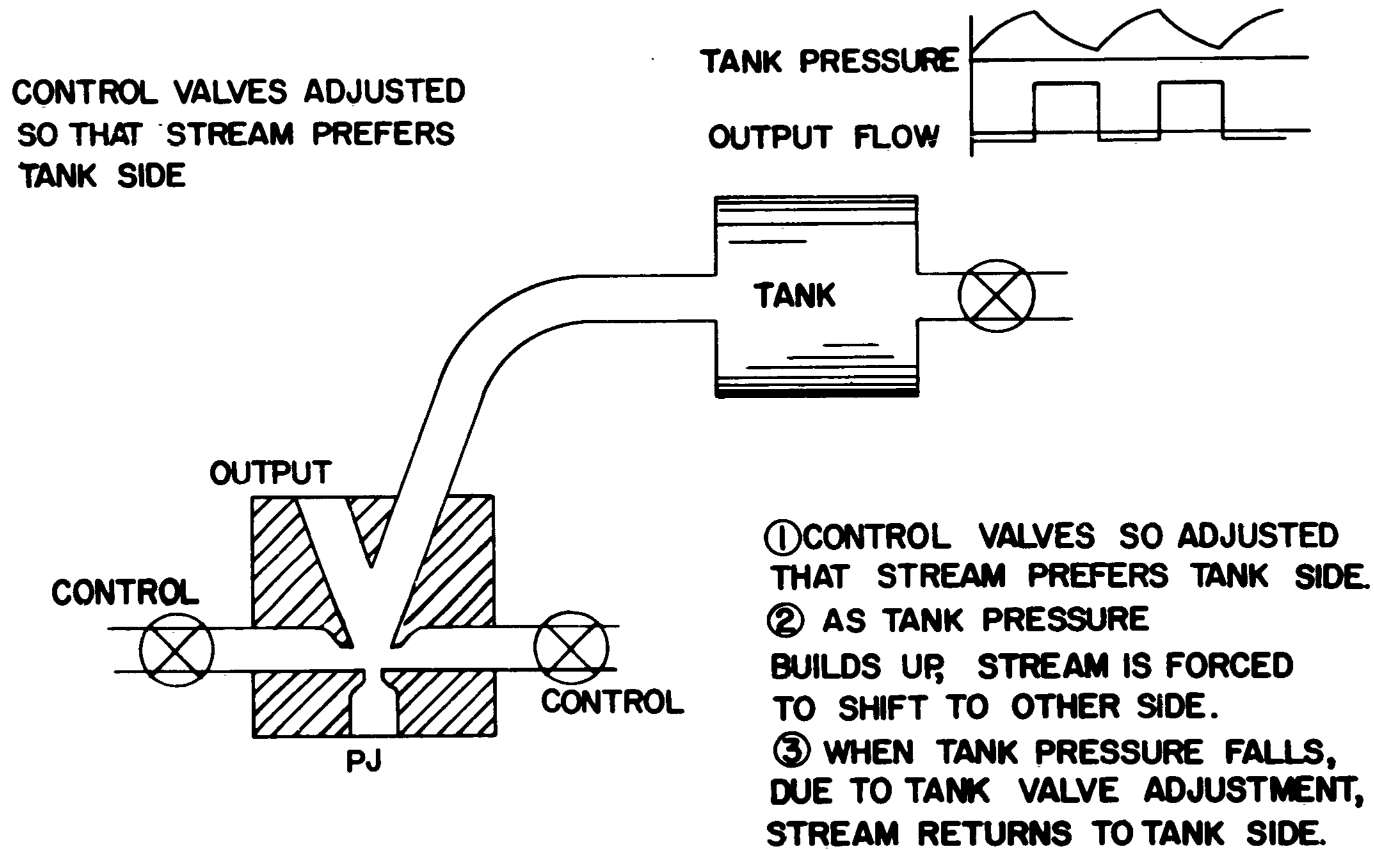

Figure 6. Oscillator, output loaded.

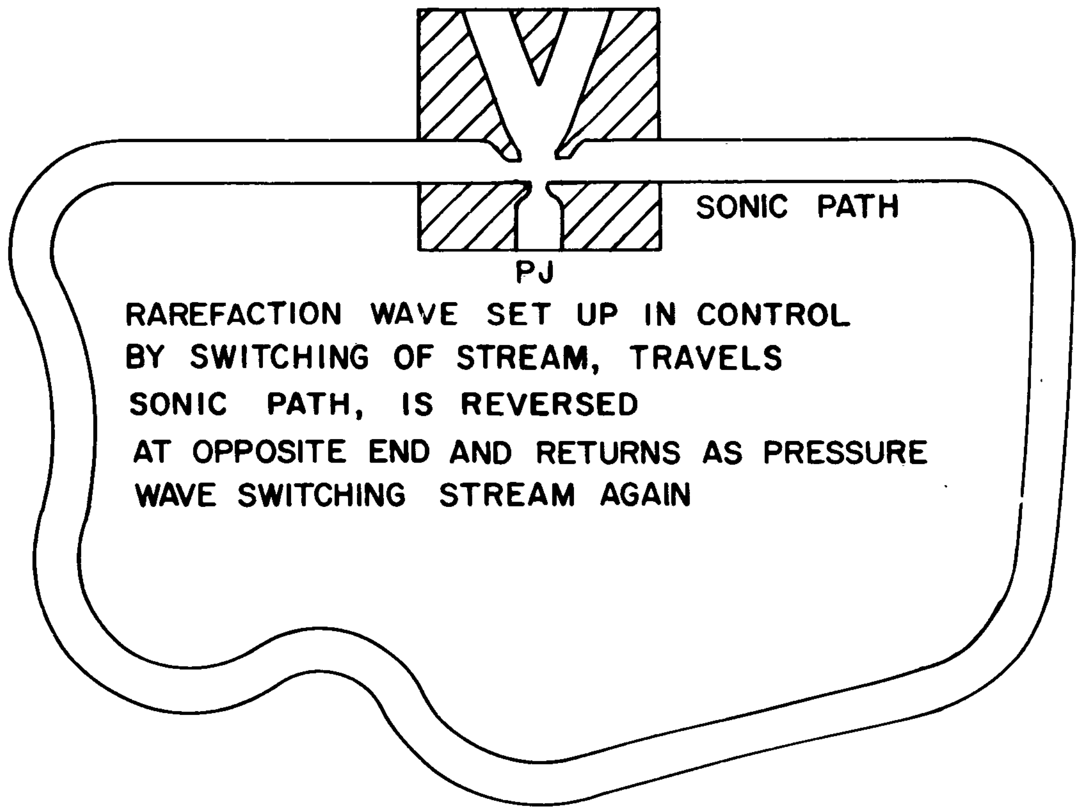

Figure 7. Oscillator, control loaded.

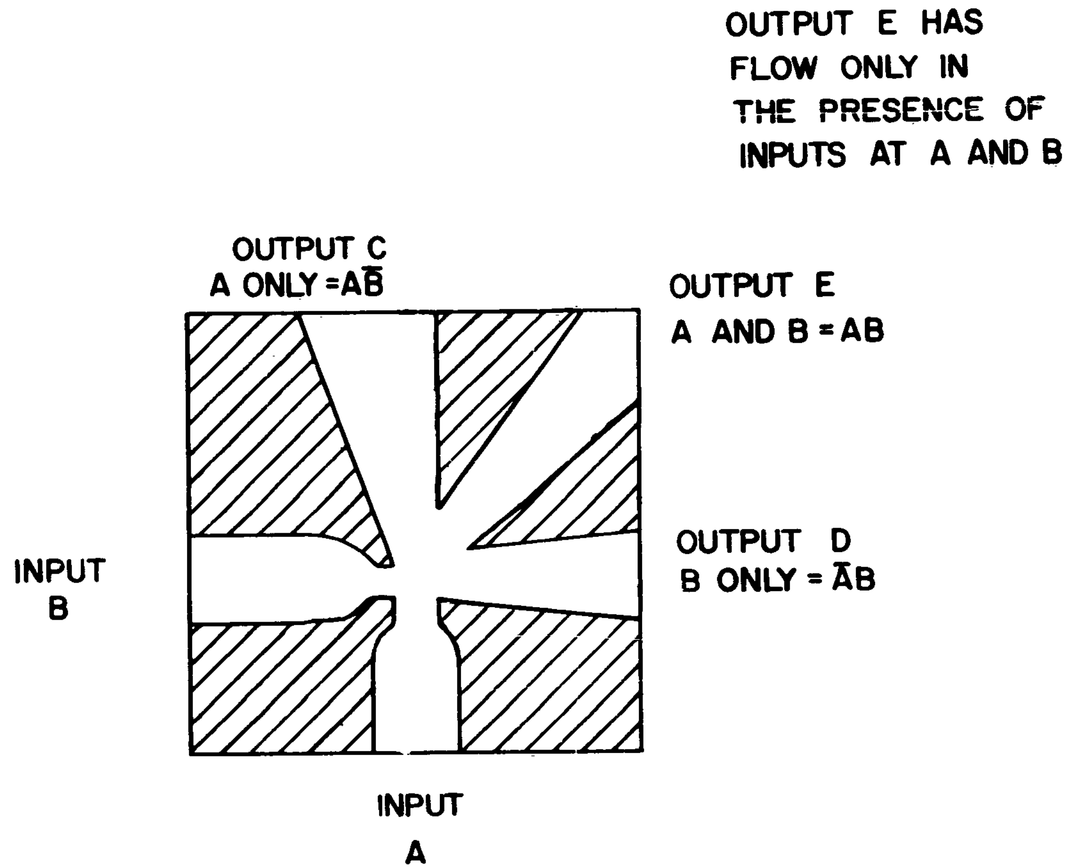

Figure 8. AND gate.

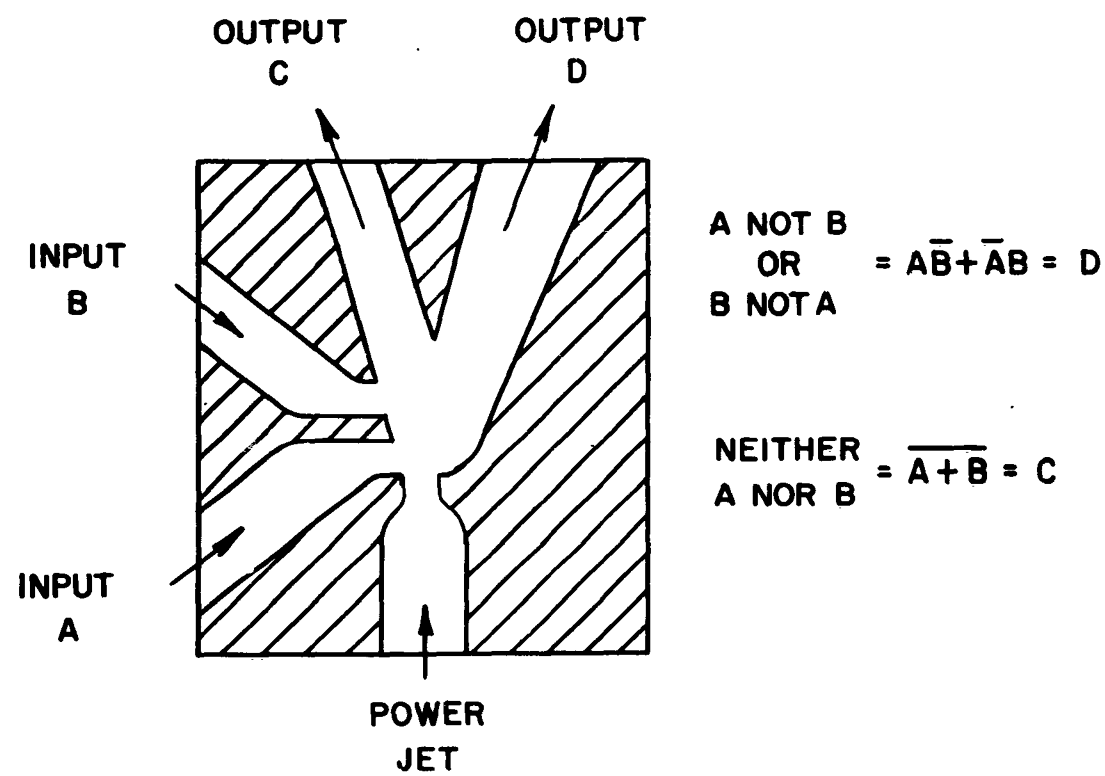

Figure 9. OR gate.

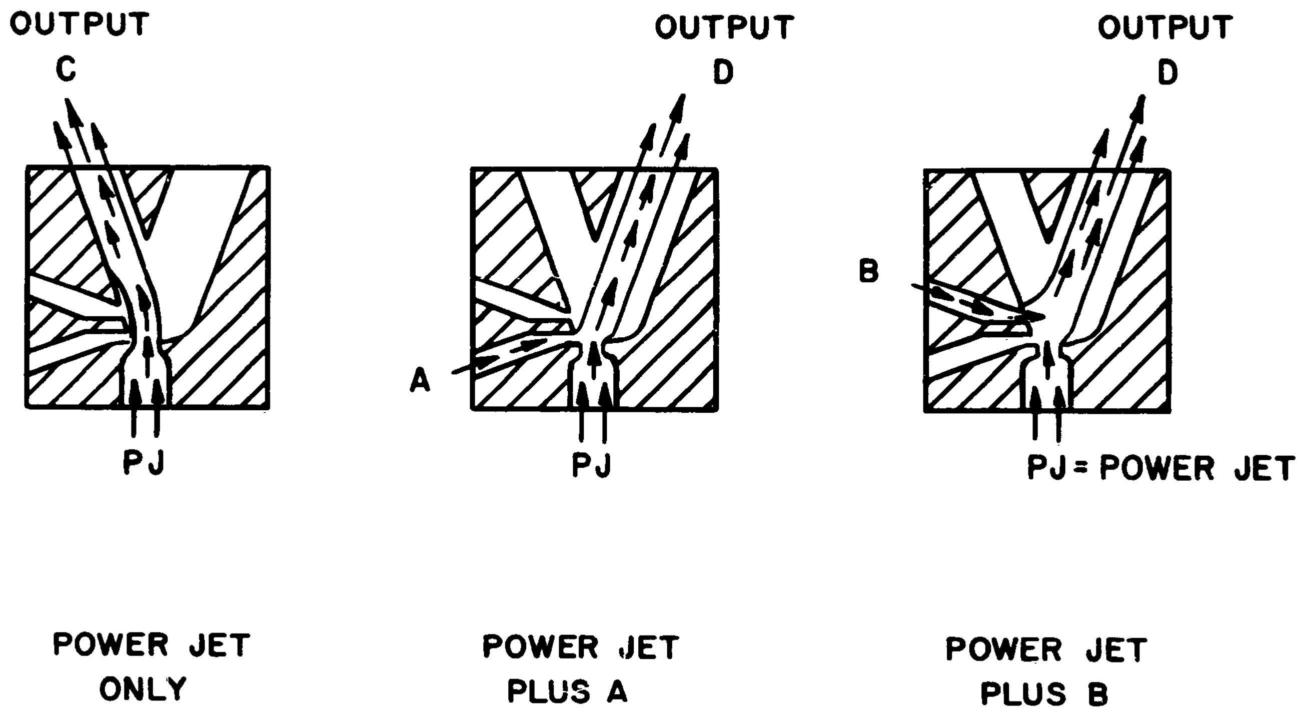

Figure 10. OR gate operation.

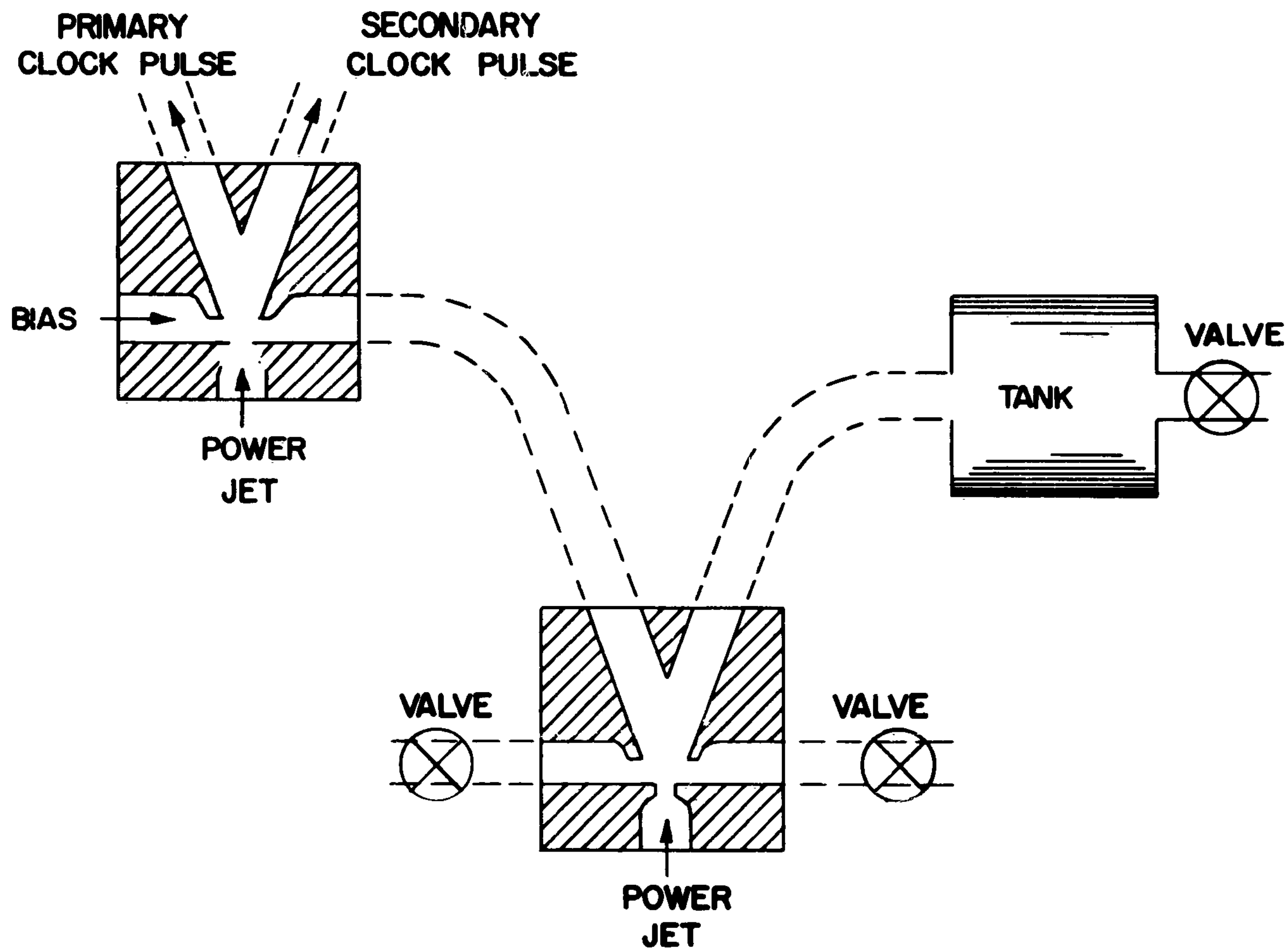

Figure 11. Clock.

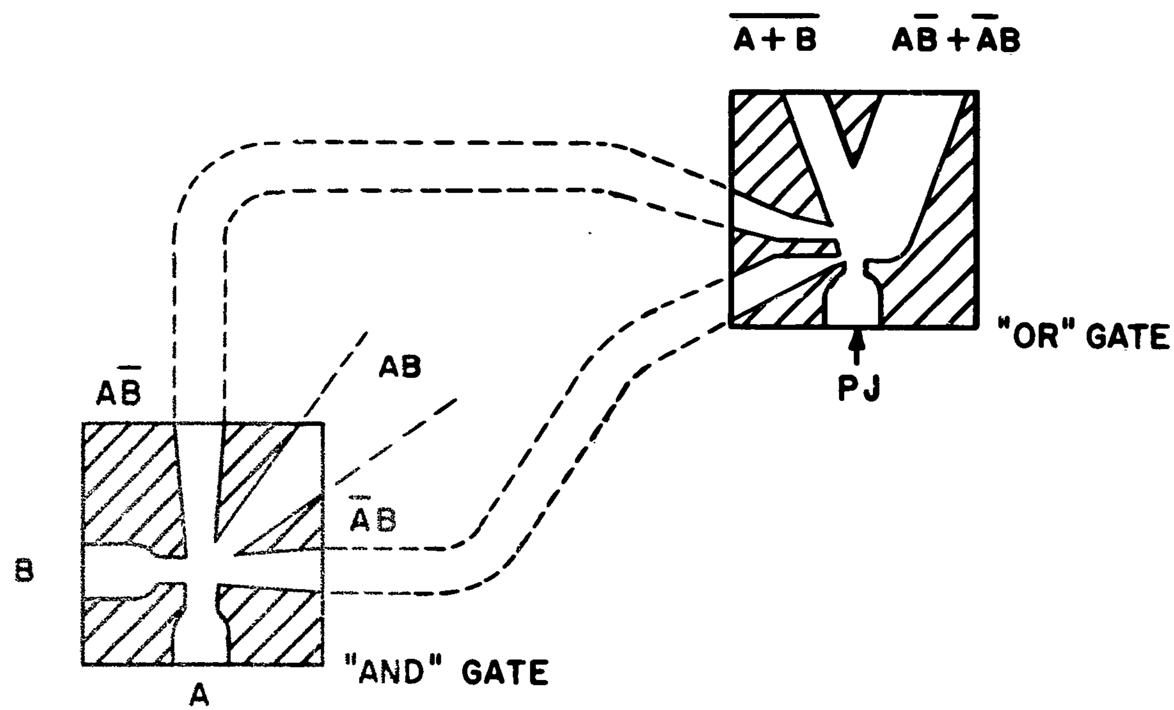

Figure 12. Half adder, AND and OR type.

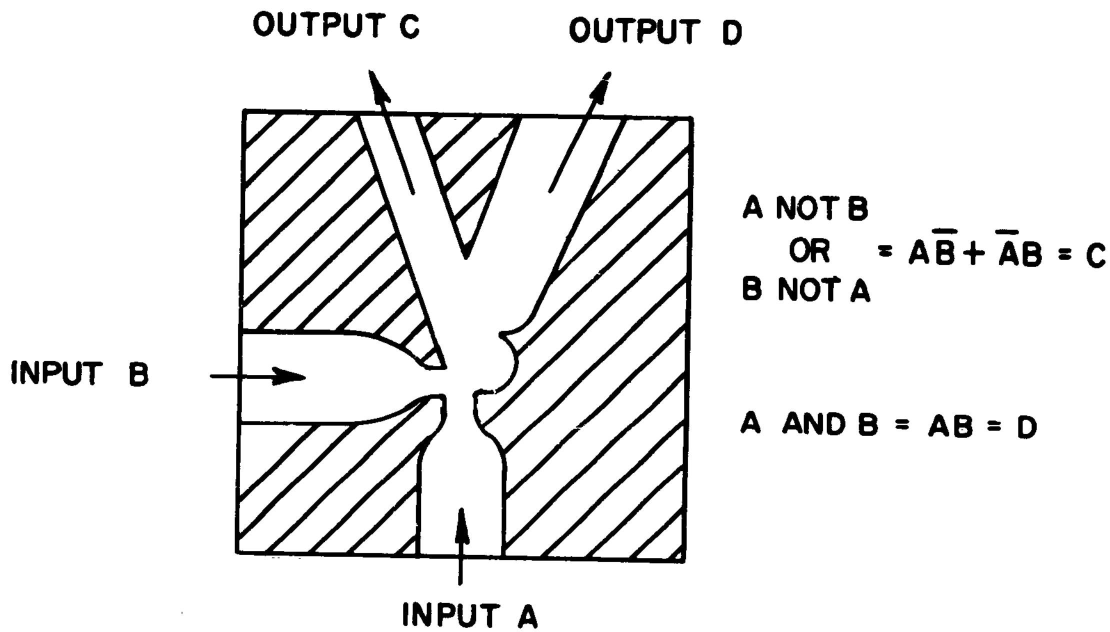

Figure 13. Half adder, hook type.

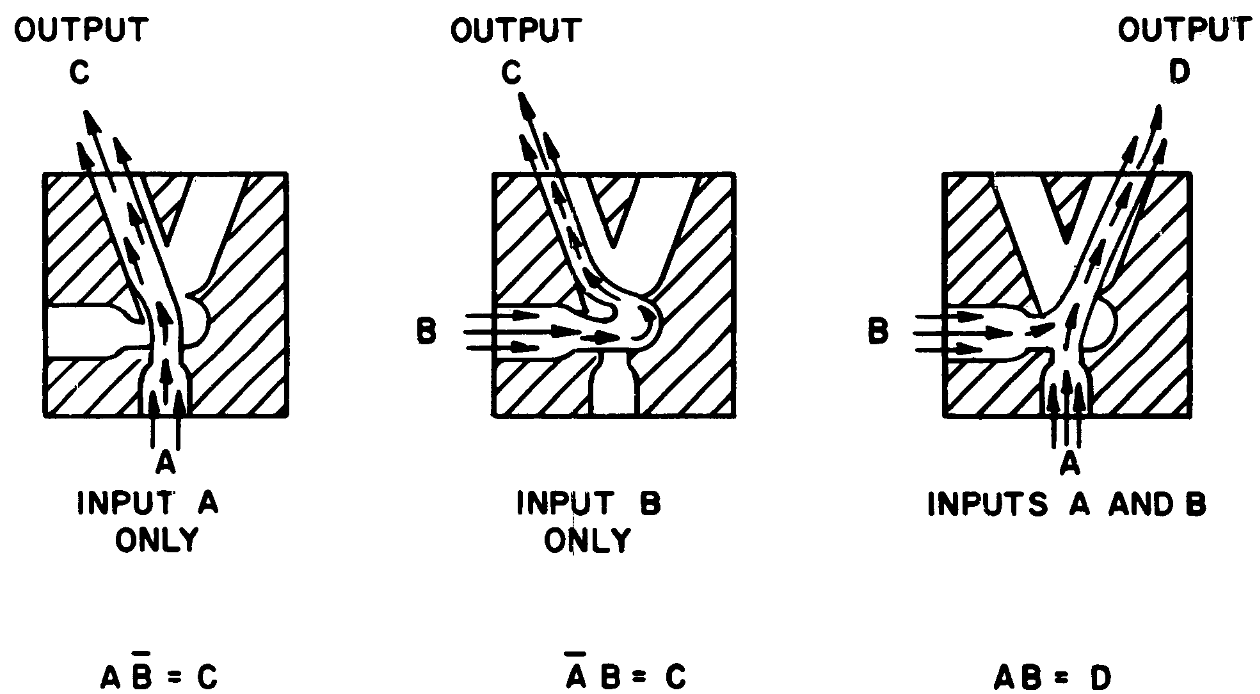

Figure 14. Half adder operation, hook type.

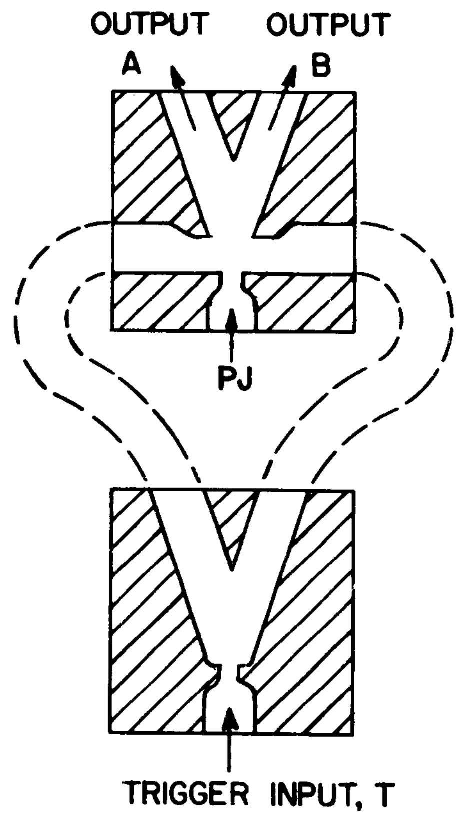

Figure 15. T flip flop.

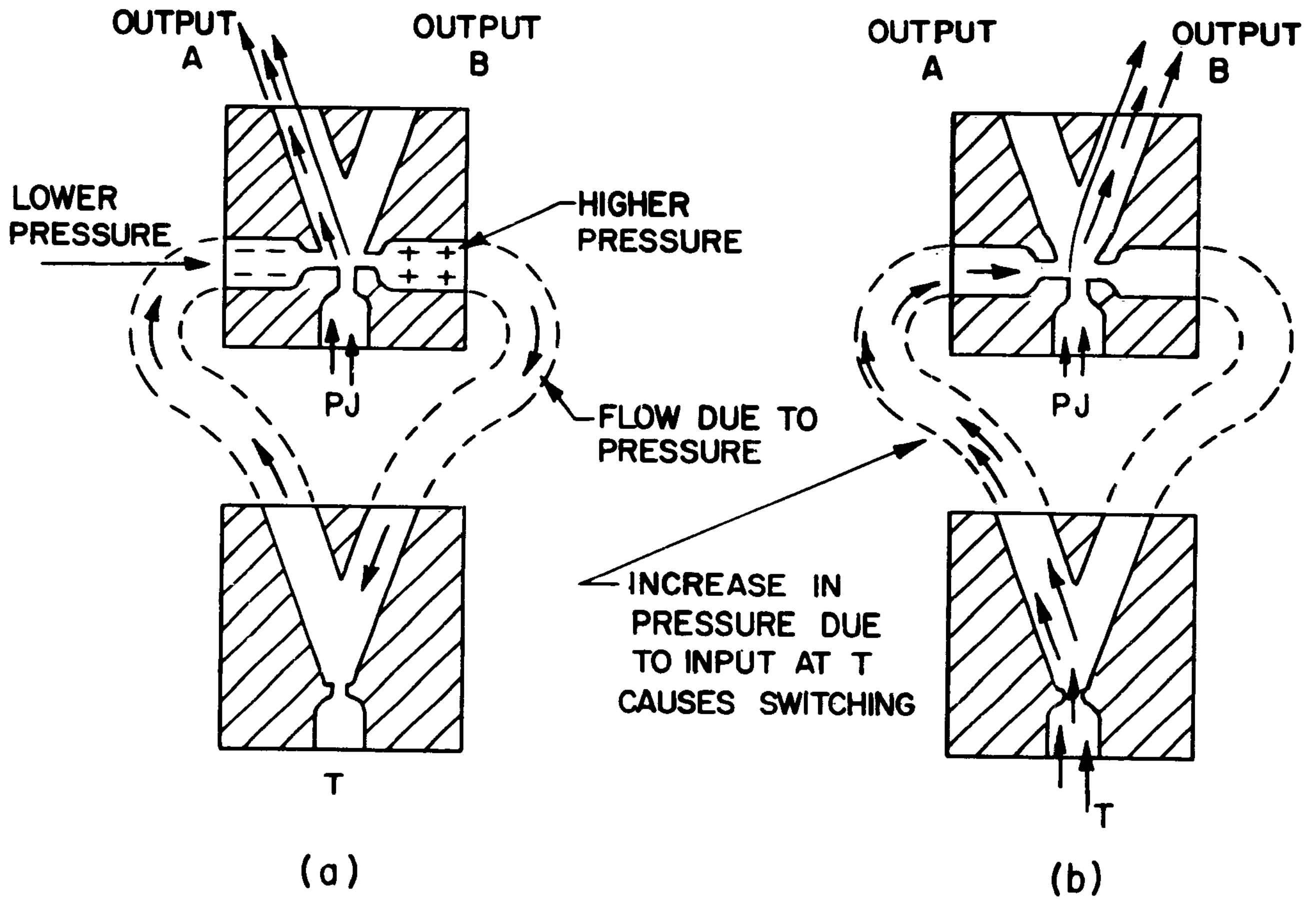

Figure 16. T flip flop operation.

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Hydraulic systems
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